Light and Lighting

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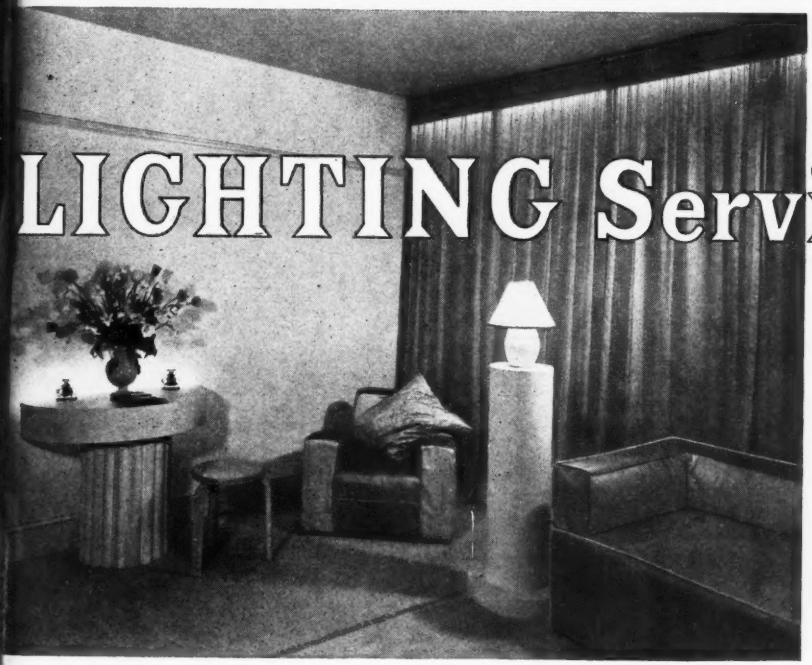

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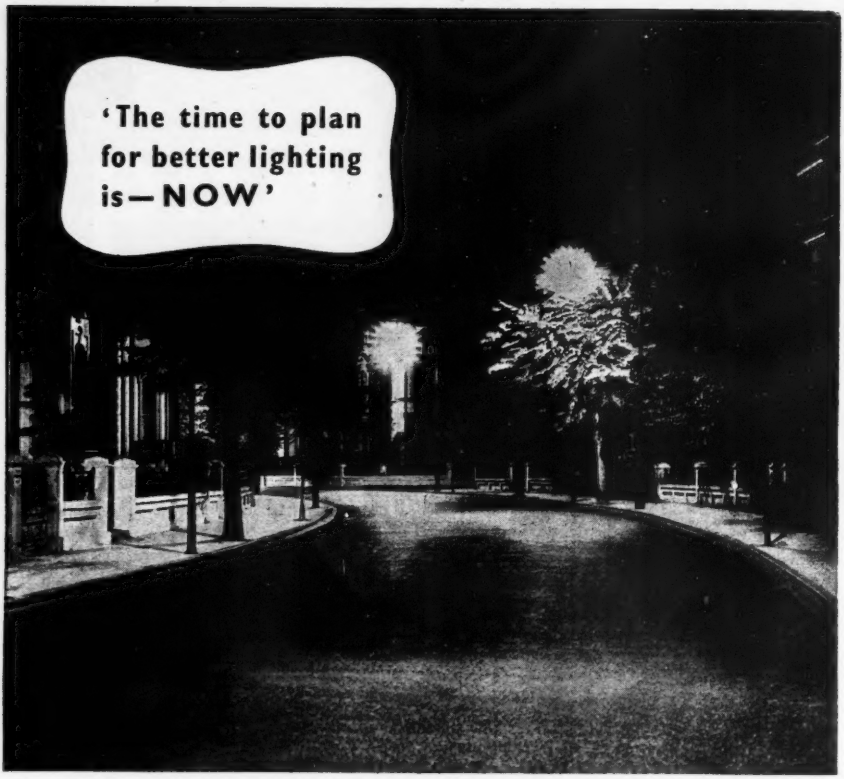

HERE IS THE PLAN—

The final report of the Ministry of Transport Committee, published in 1937, lays down for the first time recommendations for efficient and *uniform* street lighting. These form the accepted basis for a safe and economical 'full lighting' policy for every lighting authority. Experts will study the Report anew. Others will find its main recommendations clearly summarised and illustrated in 'Light on the Roads,' issued by the British Gas Council.

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Light and Lighting

Official Journal of the Illuminating Engineering Society

Incorporating "The Illuminating Engineer."

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— 1947 —

THIS journal has appeared without intermission since 1908—first as *The Illuminating Engineer* and subsequently as *Light and Lighting*. It now enters upon its 40th volume.

During this period there have been great changes; remarkable advances in lighting technique, progressively increasing interest in lighting and steady growth of the Illuminating Engineering Society, with a membership almost doubled during the war period.

This journal has benefited by the growth in available subject matter and its increased circulation. The only check has been that imposed by circumstances arising through the war, such as increased cost of production and shortage of paper.

These drawbacks will, it is hoped, be alleviated in course of time. Meantime every effort will be made to improve its contents and to render it even more useful to readers.

Attention is drawn to the note on editorial changes (p.2).

Editorial Changes

Light and Lighting (originally *The Illuminating Engineer*) was started by Mr. Leon Gaster, the founder of the I.E.S., who acted as editor up to the time of his death in 1928. Mr. J. S. Dow then succeeded him, both in the position of honorary secretary of the I.E.S. and in the editorship of the journal.

Now it is felt that the time is ripe for another departure. Whilst Mr. Dow will retain his connection with *Light and Lighting*, Mr. H. C. Weston has consented to share in the editorial duties. The convenient tradition by which the honorary secretary of the I.E.S. is also associated with the editing of the journal will thus be preserved. Shortage of paper and other restrictive influences render it difficult as yet to improve and enlarge the journal in the manner desired; but it is hoped from now onwards gradually to introduce new features and to broaden its scope in various ways.

Members of the I.E.S. will be interested to note another notable departure—the assumption by Dr. S. English of editorial charge of the I.E.S. *Transactions*. Here, too, as opportunity arises, improvements will be introduced.

In both cases the introduction of new blood and fresh ideas will undoubtedly prove of benefit.

Stage Lighting at Cheltenham

The I.E.S., Gloucester and Cheltenham Centre, on December 3, celebrated their elevation from a Group to a Centre by a special meeting held in the Cheltenham Town Hall. An address on stage lighting was delivered by Mr. L. G. Applebee, an I.E.S. member of old standing and a veteran with long experience in this special field. The address was illustrated by many effective lantern slides and by demonstrations—in the course of which the lecturer conscientiously treated his own face with grease-paint in order to show the effect of light of different colours on make-up! It was a tribute to the breezy and interesting nature of the talk that Mr. Applebee held his audience for the somewhat prolonged period of one and a quarter hours. Mr. R. W. Steel, chairman of the Centre, presided. Prior to the lecture there was an exhibition in the Town Hall, on similar lines to that arranged previously by the Bath and Bristol Centre. The Mayor of Cheltenham kindly consented to open this exhibition, and a vote of thanks to him was proposed by the I.E.S. President (Mr. J. S. Dow), who also made a few introductory remarks congratulating the Centre on their progress and enterprise at the evening meeting.

Forthcoming I.E.S. Meetings

(Provisional List)

SESSIONAL MEETINGS IN LONDON

1947.

Feb. 11th. MR. J. B. S. SMYTH on **The Brightness and Legibility at Night of Road Traffic Signs.** (*At the Royal Society of Arts, 6, John Adam Street, London, W.C.2.*) **6 p.m.**

Mar. 11th. MR. J. IVON GRAHAM on **Lighting in British Coal Mines.** (*At the E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, London, W.C.2.*) **6 p.m.**

MEETINGS OF CENTRES AND GROUPS

1947.

Feb. 3rd. MR. E. A. FOWLER on **Practical Aspects of Interior Lighting Installations.** (*At the Electricity Showrooms, The Headrow, Leeds*). **6 p.m.**

Feb. 3rd. MR. C. F. HURD on **Planned Maintenance of Industrial Lighting Installation.** (*At Sheffield University, Western Bank, Sheffield*, 10.) **6 p.m.**

Feb. 4th. MR. W. IMRIE SMITH on **The Analytical Approach to Industrial Seeing.** (*At the Electricity Showrooms, Market Street, Huddersfield.*) **7 p.m.**

Feb. 5th. MR. H. G. JENKINS and MR. J. N. BOWTELL on **High Voltage Light Sources.** (*At the Minor Durant Hall, Oxford Street, Newcastle-upon-Tyne.*) **6.15 p.m.**

Feb. 6th. MR. T. CATTEN and MR. DE RITTER on **Modern Passenger Transport Lighting.** (*At the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.3.*) **6 p.m.**

Feb. 6th. Address by the President (MR. J. S. DOW). (*At the Cardiff Corporation Demonstration Theatre.*) **3 p.m.**

1947.

Feb. 6th. MR. A. CUNNINGTON and MR. G. W. GOLDS on **Railway Lighting. Some Lessons from Experience and Views on the Future.** (*At Cheltenham.*) **7 p.m.**

Feb. 7th. MR. T. S. JONES on **Problems of Industrial Lighting and Colour.** (*At the Electricity Showrooms, Bath.*) **7 p.m.**

Feb. 7th. MR. W. A. ALLEN on **Some Recent Trends in Daylighting.** (*At the Imperial Hotel, Temple Street, Birmingham.*) **6 p.m.**

Feb. 7th. MR. T. CATTEN and MR. DE RITTER on **Recent Developments in Transport Lighting.** (*At the Heriot-Watt College, Chambers Street, Edinburgh*, 1.) **6.30 p.m.**

Feb. 7th. DR. W. M. HAMPTON on **Glassware Manufacture with Particular Reference to the Lighting Industry.** (*At the City of Nottingham Gas Dept. Demonstration Theatre, Parliament Street, Nottingham.*) **5.30 p.m.**

Feb. 11th. MR. T. WILKIE on **Street Lighting.** (*At the Corporation of Leicester Electricity Dept., Demonstration Theatre, Charles Street, Leicester.*) **6.30 p.m.**

Feb. 11th. MR. L. G. APPLEBEE on **Coloured and Directional Lighting as Applied to the Theatre.** (*At the Liverpool Corporation Electricity Showrooms, Whitechapel, Liverpool.*) **6 p.m.**

Feb. 13th. MR. H. MEYER and MR. G. A. R. TOMES on **Recent Advances in Luminescent Materials for Electronic Devices.** (*At the Reynolds Hall, College of Technology, Sackville Street, Manchester.* **6 p.m.**

Feb. 13th. DR. G. O. STEPHENS on **Recent Advances in Light Production.** (*At the Bradford Corporation Electricity Offices, Sunbridge Road, Bradford.*) **7.30 p.m.**

Feb. 28th. Annual General Meeting and Address by the President (MR. J. S. DOW). (*At the Imperial Hotel, Temple Street, Birmingham.*) **6 p.m**

(Secretaries of Centres and Groups are requested to send in particulars of any changes in programme, mentioning subject, author, place, date and time of meeting; summaries of proceedings at meetings (which should not exceed about 250–500 words) and any other local news are also welcome.)

A Presidential Badge of Office

It is now some considerable time since the idea of a badge or medallion, to be worn by the I.E.S. President during his term of office, was first suggested. Mr. W. Burnett and other I.E.S. members have devoted considerable care to the design of this emblem, which at length made its appearance at the last sessional meeting on December 10. On that occasion, the President (Mr. J. S. Dow) was formally invested with the badge by Mr. A. Cunnington, the senior past president on the spot. There was, we believe, some idea of preparing small replicas of the badge, to be retained by Presidents after their term of office has expired. We hope that this idea, too, will bear fruit and that these mementoes of office will be presented to all those who have occupied the Presidential Chair.

Defective Colour Vision

It is common knowledge that a small but appreciable proportion (greater in the case of men than women) of people suffer from more or less defective colour vision. It is obvious that some effort should be made to prevent such persons entering occupations for which they are disqualified. This question forms the subject of an informative report, prepared by a committee of the Colour Group, and published by the Physical Society, which is summarised elsewhere in this issue (see p. 6).

The chief recommendation of the Committee is that all children should be tested at school at the age of 13 or over, enabling a separation into two groups: (1) those who fail badly in the test (about 3 per cent. of boys but less than 0.5 per cent. of girls), and who should be advised to avoid occupations in which the recognition of colours is important; and (2) all children not included in (1).

In addition to this preliminary examination, more detailed pre-employment tests should be instituted in all industries and professions where normal colour vision is important.

It has occasionally been suggested that amongst I.E.S. members (now approximately 2,000) there must be some with defective colour sense. Until recently no such cases were known, but we understand that a few instances—not very serious—have been discovered.

Fluorescent Street Lighting

On December 3 last, Central London Electricity, Ltd., put into operation two new trial street lighting installations, using 5 ft., 80 W. tubular fluorescent lamps. One installation at Old Bond-street, where "warm white" lamps are used, has already been in operation for a limited period, and was described in the October issue of *Light and Lighting* (p. 187). A view of the other installation at Brompton-road, Kensington, which makes use of "daylight" lamps, is shown below.

It is anticipated that as the result

Fluorescent lighting in the Brompton Road, London, S.W.

of these tests there will be great changes in the methods of lighting busy shopping centres, and already most favourable comments have been made by drivers and other road users who have experienced this new type of street lighting. It is understood that the trial installations will be kept in operation for some weeks.

Colour in Illuminating Engineering

In what follows we give a summary of the paper on the above subject, read by Dr.W. D.Wright before the Illuminating Engineering Society in London on January 14th, 1947.

In his paper before the Illuminating Engineering Society on January 14, which was illustrated by many pleasing demonstrations, Dr. W. D. Wright remarked that interest in colour has increased substantially during recent years, partly, no doubt, owing to the advent of the fluorescent lamps which, incidentally, brings with it problems of its own.

The main factor which determines the colour of non-luminous objects is the spectral composition of the light reflected from it. This is governed partly by the quality of the incident illumination and partly by the reflection properties of the surface, which, again, depend on the chemical nature of the material and the physical condition of the fibres or particles of which it is composed. In this connection Dr. Wright exhibited curves for reflection throughout the spectrum of typical coloured surfaces.

It is naturally of interest to consider what happens to the light when it reaches the retina. Whilst precise knowledge on these processes is lacking, it seems certain that the first reaction is a photochemical one, occurring within the light-sensitive receptors in the retina, which in turn gives rise to nerve impulses transmitted ultimately to the brain. Evidently the visual response of the retina must vary with the wavelength of the stimulus and colour matching experiments strongly support the view that there must be three types of receptor which are respectively maximumly sensitive in the red, green and blue regions of the spectrum. The broad conception of these three processes serves as a basis for the discussion of colour as applied to illuminating engineering. It should, however, be remembered that much depends upon the state of sensitivity of the retina and that adaptation and contrast may play a part.

It is generally stated that there are six primary colour sensations, namely: red, yellow, green, blue, black and white. Surface colours, at least, can be quantitatively described in terms of these attributes. Alternatively the quality of a surface may be described in terms of its hue, lightness and saturation—where hue is the quality which distinguishes one colour from another, lightness the quality which distinguishes a light surface from a dark one, and saturation the quality which distinguishes a vivid colour from a pale colour.

Dr. Wright, in the next section of his paper, turned to colorimetry and the specification of colour. The experimental fact underlying colorimetry is the possibility of matching a colour by a suitable mixture of three radiations, in practice generally chosen to be caturated red, green and blue stimuli. He showed how this fact could be expressed by trichromatic formulae and graphic diagrams of which the framework adopted in 1931 by the Commission Internationale de l'Eclairage is an example. With the aid of derived curves it is possible to calculate the amounts of the three stimuli (X, Y and Z), required to match any given colour. All this can be indicated on an appropriate colour chart, which may be used as a book of patterns in identifying any particular colour—always with the limitation, however, no distinction is made between a light colour and a dark colour of the same quality.

Of great interest in the colour industry is the production of dyes and pigments which can produce both a high light reflection and a saturated or vivid colouring. In studying this question it is convenient to divide the spectrum into ten bands, each contributing 10 per cent. of the incident light. Regions of the spectrum differ considerably. Only a relatively narrow band of yellow is necessary to make up a 10 per cent. contribution, whereas at the two ends of the

spectrum much wider bands are necessary. Two factors operate the quality of the pigment and the nature of the response of the eye. Highly reflective blue surfaces, for example, can only be secured at the expense of vividness of colouring.

The specification of a colour on the C.I.E. system provides an absolute method of defining the colour quality of a light source, filter or surface. But for many purposes, for example, in choosing colours for decorative purposes, it is necessary to use a colour atlas on which the colours can be actually seen. Many forms of atlas have been devised. The charts of the British Colour Council are familiar in this country. In the United States the Munsell system and the Ostwald system are widely used.

An important point stressed by the lecturer is that the visual appearance of the light yielded by a source may be a very imperfect guide to its colour-revealing qualities. An extreme instance is afforded by the comparison of effects with a tungsten filament lamp furnished with a yellow filter, and a sodium lamp, which is monochromatic, but may apparently match it exactly.

There is, finally, the important consideration that the eye can and does accommodate itself to changes in the quality of light, provided the difference is not too extreme and no very striking departures in the appearance of coloured objects are involved. The analysis of colour adaptation is, however, highly complicated and not yet fully understood.

Defective Colour Vision in Industry

A Report issued by a Committee of the Colour Group of the Physical Society.

A very comprehensive report on defective colour vision as it affects those working in, or proposing to enter certain industries has just been issued by a committee of the Colour Group of the Physical Society.* The first chapter is a sketch, in comparatively non-technical language, of the nature and incidence of colour-blindness or, as the committee rightly prefer to call it, defective colour vision. It may come as a surprise, even to some readers of "Light and Lighting," to learn that about 8 per cent. of males have defective colour vision to an extent which would altogether preclude their employment in certain classes of work. This chapter is commendably free from any taint of colour-vision theory; it is entirely factual in treatment and gives an excellent picture of the position as it is now known.

The second chapter gives a description of the many kinds of tests which have been devised for the detection of defective colour vision. The most useful of these can be divided into four groups, viz. (i) confusion charts, such as the Ishihara; (ii) lanterns, as used by the Board of Trade, the railways, etc.; (iii) wool-matching tests; and (iv) apparatus depending on the matching of patches of coloured light or of coloured samples.

Chapter III is the longest and probably the most important, as it describes the results of the committee's very extensive investigations into the requirements of a wide variety of industries (including the Services, Police, etc.) as regards the colour vision of those employed in them and the means, if any, taken to prevent the entry of unsuitable personnel. This chapter makes most interesting reading and the contrasts between the conditions in different industries are very marked. In many cases the attitude appears to be that if anyone has defective vision, such as to make him unsuitable for a particular job, it will soon be shown up by his mistakes and he can then be transferred

* "Report on Defective Vision in Industry," obtainable from the Physical Society, 1, Lowther-gardens, S.W.7, price 1s. 6d. post paid.

to something else. Poles apart from this very rough-and-ready process is the elaborate testing carried out in industries such as the railways or the marine where, as the Report puts it, "The recognition of the colours of sources of light, frequently dim or fog-obscured, is of literally vital importance."

Some industries have developed tests of their own, frequently based on a rough simulation of the particular task to be performed in practice. The most thorough pre-vocational testing is that carried out on prospective entrants to the printing industry in Edinburgh and Glasgow, a scheme sponsored by the respective Joint Industrial Councils. In passing, it is interesting to note that even in agriculture defective vision may be quite a handicap. Tomatoes are visually picked when just turning from green to orange-red, a troublesome distinction for a fairly numerous class of colour defectives, and one worker was described as "excellent where cucumbers were concerned, but very careless in the tomato houses."

In Chapter IV the Committee examines the respective cases for pre-vocational testing and for the testing of every child while still at school, i.e., at about the age of 13. Their conclusions can be judged by the recommendations they make in Chapter V which are that all children should be tested at school by means of one of the confusion charts. Those who fail badly should be advised to avoid certain occupations. Those who make a few mistakes should be further examined, in some cases by a different form of test. Those who make no mistakes only need further consideration if they propose to enter some industry in which normal colour vision is of the first importance and for entry to which a pre-vocational test of colour vision is made. The school examination should not be relied upon to indicate that they will necessarily pass such tests

With regard to pre-vocational tests the Committee recommends the introduction of such tests in all industries and professions where normal colour vision is important. It is suggested that, in general, a confusion chart test should be used, supplemented by a trade test designed for the particular kind of task to be undertaken under normal working conditions.

The Report is most readable and it should perform a very valuable service in drawing the attention of industrialists, and those concerned with the introduction of young people into industry, to the importance of what has hitherto been a very neglected item on the list of qualifications for particular classes of work. It was fully discussed at a meeting of the Colour Group held at the Royal Society of Arts on December 19. After Mr. H. M. Cartwright, the secretary of the committee responsible for the Report, had given an outline of its contents, certain aspects were dealt with by specialists with different interests in the matter. The first was Dr. A. H. Gale, a medical officer of the Ministry of Education, who gave it as his personal opinion that the introduction of a test of every school child would mean a not inconsiderable increase of the load on the school medical service. Only in certain classes of school, e.g., the grammar schools, he thought, could the testing be done by a member of the teaching staff. He felt that pre-vocational testing of those who definitely wished to take up a career in which colour vision was important would be more practicable than a mass test of the whole school population.

Mr. R. F. G. Holness, of Messrs. Waterlow and Sons, Ltd., urged caution in the application of colour-vision tests, citing a case where the rigid application of such a test would have resulted in preventing the entry into the printing trade of someone who had in fact made it his career and had suffered no disadvantage. Dr. J. Sharp Grant, the medical officer of the L.N.E.R., was emphatic in urging the application of a test at the earlier stage so as to prevent possible waste of time on the part of a youth who subsequently found himself barred from the line of work for which he had been preparing. This view was endorsed by Professor L. C. Martin, who also dealt with the need for ensuring the highest possible reproducibility in the tests used, particularly the lantern test.

Several other members took part in the discussion and most seemed to favour the application of the test during a child's school life. Dr. W. D. Wright emphasised that the school test proposed was a preliminary screening, to be supplemented later if the circumstances, e.g., the particular kind of work chosen, demanded it.

Comfort in the Home

In an article of this title published in the October issue of *Mother and Child*, Professor G. P. Crowden and Dr. T. C. Angus point out that good lighting is not only necessary for various domestic tasks, but should also impart an atmosphere of cheerfulness and brightness to the home. But in order to appreciate the various ways in which such lighting may affect our visual comfort and ability to work it is necessary to bear in mind certain factors concerning the structure of the eyes and how they work. The eye fortunately possesses considerable, though not unlimited, powers of adaptation which enable us to see in bright sunlight or in candle light. In a bright light the pupil of the eye contracts and a sharp definition is possible, whereas in a poor light the pupil dilates to admit enough light for us to appreciate the image of the object which is focused on the retina, but, as in the case of a camera, such a widening of aperture makes the photograph less sharp in its finer details.

Natural Lighting

Unless *some* direct light from the sky or clouds (not necessarily the sun) illuminates the object we wish to see, the value of daylight illumination will, in general, be insufficient for continuous close work. A simple way of ensuring that the daylight lighting is adequate is to place a mirror on a table between yourself and the window and note whether or not any unobstructed sky can be seen reflected in the mirror. Although windows themselves may be adequate in size for the daylight lighting of a room the actual illumination may be insufficient owing to curtains and blinds obstructing the passage of daylight; it is also surprising how much light is cut off by dirty windows.

Artificial Lighting

When considering the best use that can be made of artificial lighting in a room it must be remembered that the light should not shine directly in the eyes, but on to the object which it is desired to see. There is good reason for the familiar recommendation that light should shine over the left shoulder so that the shadow of the hand does not fall on to the work.

It should be noted that a great loss of light may be caused by dirty or dark coloured ceilings or walls, a defect which may easily be remedied by the householder himself by the selection and use of a suitable wash or distemper. It is easily possible for as much as one half of the light from a well-made fitting to be directed upwards; indeed such a distribution of light is to be recommended.

Electric bulbs should be frequently cleaned, particularly in the kitchen, where steam and fumes from cooking cause a film to be formed very rapidly on the glass surface. It has been shown that, in a few days, 25 per cent. of the light from a bulb may be cut off by such a film of dirt.

Reading lamps or lamps for close work should be carefully selected. Speaking generally, lamps with small shades very near the table are undesirable, for they produce a local patch of brightness surrounded by an area in which the intensity of illumination decreases rapidly. Such lighting may cause unnecessary fatigue as the eye repeatedly adapts itself as we read down the page of a book or column of a newspaper, or glance aside. It is, of course, essential that the eye should not catch sight of the bulb, either when occupied in reading or if the head is raised while working.

The article includes a photograph of the Lighting Laboratory at the London School of Hygiene and Tropical Medicine before it was destroyed by enemy action in 1941. It is hoped to re-equip this laboratory so that it may continue to reinforce the good work of the Department of Applied Physiology in the lighting field.

No doubt this aim will receive sympathetic consideration from leading firms in the lighting industry.

Photo-Electric Cells in Commercial Lumen Photometry

By R. TUCKER

The increase in the quantity and variety of electric lamps brought about by the rapid growth of the electric lamp manufacturing industry during the last thirty years made it necessary for the industry to develop commercial photometry to replace the laborious methods in use at the time. Whilst the visual instruments hitherto available were, in general, superior in accuracy and reliability they were slow in operation and called for a certain standard of skill on the part of the user. What the industry demanded was a "Photometric Section," manned by production operatives rather than laboratory assistants, to determine the light output of selected samples of lamps taken from hour by hour production completed by the factory, to verify the calculations from which the lamps were designed and manufactured, and to provide data from which further lamps might be made.

Ulbricht globes and spherical integrators had enabled mechanical integration to supersede the laborious method of mathematical computation of total flux emitted rather than a measure of the flux unidirectionally, which was now expressed in "lumens," with efficiencies in terms of "lumens per watt." Visual photometry, using the Lummer Brodhun type of head comparing intensities by equal illuminations of a screen, and producing equality by change of distance, is still the most accurate. The eye alone can only say that of two sources one is more bright, or less bright, than the other. It cannot compare quantitatively. The demand was, however, for some instrument, of the type of the thermo-pile, which would cause a measurable electrical current to flow between the sections of the couple when exposed to light. It was found that both selenium and black copper oxide exhibited these "photo-electric" effects, and the development of cells employing these substances has proceeded steadily since the turn of the century, resulting in the modern barrier-layer type of selenium-iron photo-cell.

Parallel with these researches on selenium and other photo electric substances work developed on the photo-emissive cell, which consists essentially of a light-sensitive surface (e.g., caesium or potassium on silver oxide), from which electrons, emitted when the surface is exposed to light, are collected by an anode, the two electrodes being in vacuo on a potential gradient. In this way current flows through the cell and its external circuit and may be measured.

With this latter type of cell much of the earlier commercial work appears to have been done despite the fact that the photo-currents were only of the order of 10^{-2} or 10^{-3} micro-amperes, and some means of amplification was necessary before its output could be measured. The amplification factor of the triode was used and the current from the cell, developed across a large grid leak, was fed to the grid of such a valve, causing a measurable change in anode current. If a voltage in the opposite sense be applied to the same grid, there will be a tendency for the change of anode current produced by the photo-cell to be cancelled, and when the voltage is equal to that developed across the grid leak by the photo-current, then the anode current will be restored to its original value. If the restoring voltage be supplied from a calibrated potentiometer and the value of the grid leak resistance be known, then Ohm's Law will enable the photo-current to be calculated. Since this current is proportional to the amount of light flux falling upon the cathode of the cell, it will be possible to measure the amount of light flux present, provided the amount of photo-current produced by a known amount of flux is known.

This latter type of cell provided the means of comparing the illumination of the window in the Ulbricht integrator without resorting to the cumbersome equal-brightness method. If we place

within the integrator a lamp of known lumen value, then the potentiometer reading will correspond to that lumen value—in fact, the reading can be used to give a direct indication of the luminous flux from the source.

This photo-cell valve combination is only the bare outline however, for it is obvious that it would be beyond the expectation from any factory-hand to manipulate anode current virtually at will from this method. A "balance" method is indicated, and this is achieved by placing another valve, matched for V_a I_a characteristic with the valve previously discussed, in parallel with it and adjusting the grid bias so that when there is no output from the photo-cell there is no difference in potential between the anodes of these two valves. A "null-point" galvanometer slung between these anodes will simply and accurately indicate the fulfilment of this condition. Thus, since the operating conditions of this second valve do not change, it can be used for comparison when measuring, the galvanometer showing "null-point" when the valves are working under the same conditions. And it is not asking too much of any operator to determine when a centre-zero galvanometer is reading zero!

Thus we have a method that is neat, easy to operate, rapid, accurate, and reliable; but it has its disadvantages in that the cell is fragile, the tiny photo-currents are upset by stray fields or atmospheric and dust charges, and that the apparatus is costly and requiring of skilled maintenance. Makers of modern cells have done much to eliminate these failings, and have produced cells with milliampere output, cell and valve in one evacuated envelope to reduced cell-grid losses and above all, amplifier-balance kits which are reliable and almost fool-proof. Installation of this type of photometer is complex and costly, but is compensated by the excellent service which is given for many years.

The greater sensitivity of the rectifier type of cell led to the replacement of the complex amplification system of the emissive cell by a simple millivoltmeter or galvanometer measuring light-on-cell in terms of the potential difference between its terminals. Since the voltage generated is a function of the amount of light and the sensitive area exposed, then by varying the latter by means of an aperture a simple condition wherein one lumen will produce one millivolt (or microamp if a microammeter be used in place of a millivoltmeter) can be obtained.

The more favoured method is to develop the photo-current across an external resistance in the form of a rheostat, and tap off the required amount to "set" the photometer. The principle of direct-comparison measurement is the same for this method of photometry as with the emissive cell and the photometer is "set up" in the same manner.

From the standpoint of simplicity, this method is preferable to the emissive-cell apparatus, but the speed of measuring is limited by the period of the galvanometer used and the accuracy is very dependent upon the keenness of the eye of the operator.

If this type of cell is placed directly on the surface of the integrator—and its flat shape enables this to be done very easily—it is found that the heat stored in the integrator by the lamps burnt within it gives rise to more errors—for this type of cell is more sensitive to ambient temperature than the glass enclosed type. If, however, it is placed within a secondary sphere in the same way that the emissive cell is mounted, then much of the sensitivity is lost and the cell's greatest advantage is diminished.

Probably the most frequently tendered reason for the adoption of the barrier-layer cells for commercial photometry is their overall simplicity and robustness. Their spectral response is also nearer the Average Eye response and thus needs less correction.

If one adheres faithfully to the direct comparison method, differences in quality of light present no difficulty as the photometer can be adjusted to meet

colour changes by resetting with a standard of the same colour temperature. It is preferable, and far less expensive, to adjust the spectral response curve of the cell so that its output may be directly proportional to quantity of light over a given and known range of colour. This is accomplished by interposing filters of glass, liquid in glass (though rarely in commercial work), or gelatine in glass, between the window of the integrator and the cell, with the C.I.E. Average Eye curve of colour response as the objective.

Each cell needs individual treatment and should always be considered as an incomplete unit without a filter despite the changes of response curve caused in all cells by changes of atmospheric temperature and humidity, for these changes are negligible. This, then, is the commercial photometer whichever cell is used. Once the spectral response of the cell is adjusted all the operator has to do each day is to adjust the aperture and/or rheostat with a "standard" (or lamp of known performance) burning within the integrator so that lumens or multiple lumens are shown on the indicating instrument, remove the standard and continue measuring, easily and accurately.

The existence is assumed of standard lamps the working characteristics of which have been accurately determined in a laboratory. They are highly prized in photometric departments, for without them even the finest equipment is useless; most of them are specially made for the purpose and embody every refinement of which lamp makers are capable. It is customary to have them calibrated at the National Physical Laboratory.

Generally speaking, the colour temperature of incandescent filaments, relative to the Black-body standard, is closely related to the luminous efficiency of the filaments (efficiency being the fraction lumen/watts). Use is made of this relationship when checking linearity, for if a cell is linear over a given range of efficiency—say, from 5 L/W to 25 L/W, then it will be reasonably linear over a corresponding range of colour temperature—say, from 2,400° to 2,950° K. This enables the operator to know if the photometer is working properly without demanding that he or she understands colour temperatures and saves time and worry if colour temperature standards are not available.

Correction of the photo-cell to rectilinear response over the working range is effected by trial-and-error methods, using the standards discussed above and filter combinations adjusted until the appropriate one is attained.

Commercial photometry is very successfully coping with the tasks set before it. Of the two types of photo-cell discussed here, the photo-emissive variety seems preferable at the moment, although the publication of more data on the new multiple cells may result in change. The photo-emissive cell needs maintenance by someone with a knowledge of radio and electronics, but the author's experience has been that the rectifier cell is far more liable to develop fatigue troubles than the emissive type and needs more frequent attention.

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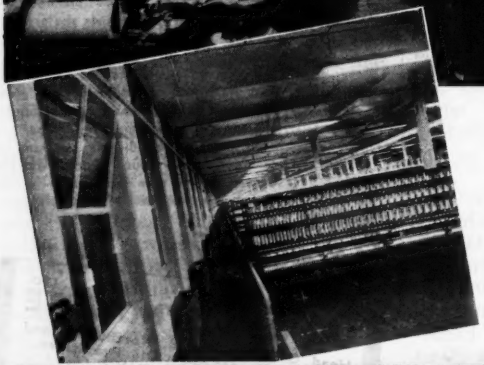

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Illumination in Offices and Homes*

By A. A. KRUITHOF and H. ZIJL

An attempt is made in this article to solve the problem of the most suitable values of illumination for the activities of office and home. In every human activity the task of the eye is to distinguish some detail against a given background under a given illumination. The requirements made upon the eye can be characterised by the size of detail to be observed, the contrast between the detail and the background, the time available for the observation, and the length of time during which the activity is continuously performed. Investigations have shown that for normal work (size of detail about three minutes) the performance of the eye distinctly improves as the illumination is increased up to about 4 lumens/sq. ft., whilst for fine work (size of detail about one minute) there is still a marked improvement in performance up to about 100 lumens/sq. ft.

Reference is made to the work of Luckiesh and Moss, who used various criteria of fatigue. The most obvious, i.e., the criterion which is most closely connected with the act of reading itself, is the decline in reading speed. This decline, however, is always found to be only slight, and consequently to exhibit only small differences for a very wide range of values of illumination. This may be understood to mean that under worse visual conditions the eyes are stimulated by the brain to correspondingly greater effort. The relation between fatigue and speed of reading is thus, for the greater part, lost. Hence this is not a very suitable criterion of fatigue. Another criterion, used by Luckiesh and Moss, is the frequency of the involuntary blinking during reading. This criterion is less directly connected with the act of reading than the speed of reading, but there is reported to be a satisfactory correlation between greater difficulty in reading and more rapid blinking. Results show that under the higher illuminations less fatigue occurs: between 1 and 100 lumens/sq. ft. a steady improvement can be observed with increasing illumination, although the improvement per unit increase in illumination rapidly becomes less at higher levels.

Offices

For office lighting the utility factor is most important. Both for the initial installation and for possible alterations it is primarily the economic advantages and disadvantages that are weighed. It has been shown that an increase in illumination will result in an increase in the production of the employees representing a certain money value. This increase will be considerable at low levels of illumination, but will become less and less at higher levels, until finally there is no advantage at all. Costs show an opposite trend. The additional expenditure entailed, for example, by doubling the illumination intensity is less at a low level of illumination than at a high level. It is apparent, therefore, that in increasing the illumination a point will be reached above which the benefits of higher illumination will be outweighed by the cost. Owing to advances in technique with the course of time, however, costs tend to fall in relation to advantages, i.e., the most economical illumination level tends to rise.

Since some time always elapses before practice adapts itself to technical progress, in most offices one encounters levels of illumination which are lower than those considered to be the most economical. As long as the level is not too low, the difference is only a question of utility. It is, however, clear that at too low intensities phenomena must occur which can no longer be expressed purely in money value, but which already fall within the sphere of hygiene, i.e., they will give rise to complaints by the employees of fatigue, headaches, etc. General experience in the practice of factory and office lighting is that the limit above which these phenomena are no longer frequent for

* Philips Technical Review, Vol. 8, No. 8.

activities such as reading lies at about 10 lumens/sq. ft.

The Living-Room

The situation in the living-room is quite different as the many tasks which are carried out therein call for a variety of levels of illumination. In this article consideration is given to the illumination which should be employed when the room is used primarily for work. In the discussion of office lighting it was evident that from considerations of hygiene, and activities such as long-continued reading, illumination of at least 10 lumens/sq. ft. should be provided. This minimum limit may therefore be considered applicable to the living-room though, having regard to the poorer vision of older persons and the greater difficulty of tasks such as embroidery, etc., it is better to allow a 50 or 100 per cent. higher illumination.

The solutions arrived at for the office, however, would not in general be acceptable in the living-room since, even though it is used as a workroom, a domestic atmosphere is desired which cannot be combined with the technical austerity of purely utility illumination. Aesthetic considerations come first; the lighting fitting must harmonise with the interior—not only when lighted, but also in the daytime. The shape and colour of the lighting fitting by day are usually the criteria which decide the choice of fitting, while the illuminating technical characteristics are usually given too little consideration. The illumination provided is often quite insufficient, even when using the largest lamp permissible conducive with moderate heat development—to say nothing of such weaknesses as poor distribution of the light flux and neglect to provide against glare.

It is no wonder that in almost all living-rooms values of illumination are found which lie far below what is desirable in a workroom. If the eye protests too strongly, recourse is usually had to extra local illumination. This, however, when several persons are working at the same time, cannot be considered a satisfactory solution.

In the present day it is without doubt technically possible to secure lighting conditions of living-room lighting of sufficiently high level, and in this respect two points have been found to be of great importance. Firstly, the aesthetic acceptability of an illumination depends very much on the relation between the brightnesses of the surfaces occurring in the room (furniture, ceiling, walls, etc) —the correct technical construction of the fixture to distribute the light in the desired manner over the working surface and surroundings no longer presents any difficulty with modern technical development. Secondly, the level of illumination considered as being "pleasant" is related to the colour of the light—a change from the reddish light of incandescent lamps to a whiter light may in some cases give an interior a more agreeable aspect. The possibility of such an improvement in colour is now afforded by the development of luminescent lamps, whilst at the same time the cool nature of the radiation therefrom eliminates possible difficulties arising from undue heat development.

It may be hoped that these new possibilities will ultimately remove the great difference between the desirable and the actual illumination intensity in the living-room when it is used as a workroom.

The Control of Street and Traffic Lighting

Much attention is commonly devoted to the distribution of light from street lighting fittings. Another aspect, less often discussed, is the control of street and traffic lighting. This formed the subject of a paper by Mr. F. M. Hale given at a meeting of the Glasgow Centre of the Illuminating Engineering Society on December 5. The paper covered a wide range of controls for both gas and electric street lighting, reference being made to such methods as hand, clock, pressure wave, photo-electric and ripple control. The limitations and advantages of these systems were compared and the operational features were demonstrated by working models. Mr. Hale also discussed the factors affecting the legibility and conspicuity of traffic signs.

Education in Illuminating Engineering

In presenting his chairman's address to the Tees-side group on November 20, Mr. H. V. Field reviewed the progress that had been made in illuminants and illumination measurement during his lifetime. He traced the development of electric filament, arc and discharge lamps from their earliest forms, and mentioned the many difficulties which had arisen and which had been overcome in making practical use of these many inventions.

In his concluding remarks Mr. Field commented on education in illuminating engineering, a subject with which, from his close association with technical education, he is particularly able to deal. In spite of the extent to which lighting affects the daily life of everyone, *Applied Light* still finds too small a place in the curricula of our technical schools and colleges; although the subject of Light, treated as a branch of pure science, is accorded a substantial place in the curricula of physics courses.

Applied Light is found chiefly in courses in electrical engineering and architecture. Owing to the limitation of time which results from the substantial amount of other work which must be included, lighting in the former type of course is generally restricted to simple treatment of electric light sources only, with a few lighting calculations and a little photometry; as a rule no mention is made of the problems of brightness, glare, contrast, etc. In architectural courses some time may be devoted to the decorative value of light but little to the types and characteristics of light sources and lighting equipment.

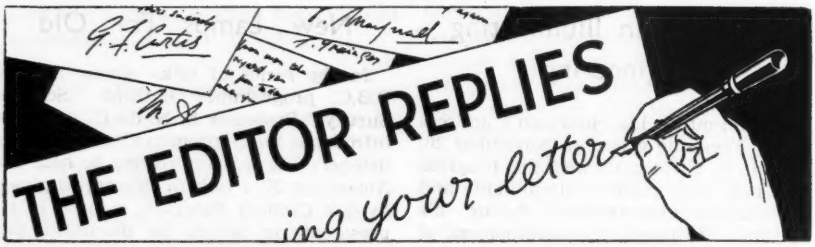
This state of affairs is slowly being remedied, and contacts between architects and lighting engineers are increasing. The recognition of the need for specialised training, linked up with examinations conducted by an examining body of repute, was realised some years ago, and in 1938 the City and Guilds of London Institute introduced their scheme. The war has had an unfortunate retarding effect on the development of courses for these examinations, but a substantial extension is to be hoped for in the future as the number of openings for lighting engineers continues to grow, and adequate facilities for their training should be provided.

New Lamps For Old

In the series of talks given in the B.B.C. programmes entitled "Science Survey," Professor E. N. da C. Andrade introduces many prominent scientists to listeners. It was interesting to hear on November 27 a talk in this series given by Sir Clifford Paterson, a past I.E.S. president, in which he discussed the development of fluorescent lamps.

Sir Clifford explained that whereas with the ordinary filament lamp nearly all the energy supplied is converted into heat instead of light, with the new type of lamp light is emitted by a cold glowing column of gas in a glass tube. These lamps have been developed from the neon advertising sign which, however, gave only light of one colour, i.e., deep orange. It might be anticipated, as every gas and vapour gives a distinctive colour when excited by the passage of electricity, that there would be a large choice of colours. This is unfortunately not true, as for various reasons most gases and vapours cannot be applied to the practical production of light.

Of those which are effective, mercury vapour is the one used in the new fluorescent lamps but, as is well known, the light given out by mercury has no red constituent. The discharge, however, radiates a large amount of ultra-violet light, and it was found that certain luminescent materials glowed with brilliant colours when exposed to this type of radiation. The search then began for suitable luminescent powders which could be used in this way to produce a new type of light source giving white light for interior illumination. The problem of obtaining an efficient luminescent substance is one of introducing very small, carefully controlled amounts of certain elements into the parent material with the exclusion of others which would be detrimental to the amount and quality of light produced. As an example, it was mentioned that a few parts in 100,000 of copper is sufficient to make zinc sulphide luminesce a brilliant green, whilst a few parts in a million of iron would poison the effect and reduce the brightness. As the result of such research the fluorescent lamp gives three times more light than the ordinary electric filament lamp using the same amount of electricity. It is available in various colours, the daylight version being very suitable for use in those parts of buildings which receive inadequate natural lighting.



I have been interested in a letter from Mr. R. R. Holmes, who comments on the proposed substitution of **"lumen per square foot"** for **"foot candle."** From the scientific standpoint this step is doubtless expedient, and it is already coming into operation. Nevertheless, I share a certain misgiving felt by Mr. Holmes about this term, which is certainly cumbersome and awkward, especially when it is necessary to repeat it in conversation.

Mr. Holmes points out that the use of the term "lux" on the Continent largely overcomes this difficulty. It is, however, associated with the metric system, and Mr. Holmes therefore suggests the use in this country of **"lume"** (one "lume" being one lumen per sq ft.).

There is something to be said for this suggestion, which I commend to the attention of the B.S.I. Committee concerned with nomenclature and symbols. It has, however, one drawback (which applies equally to "lux") that it is **not self-explanatory.** One great merit of the foot candle is that it does convey a mental image and is readily explained in terms of the candle and the foot—though it has been argued that those to whom the term appeals are sometimes apt to believe that they know what it means when in fact they do not!

Attention has been drawn to a new device in preparation for Covent Garden Opera House, the **"penumbrascope."** I understand that this consists essentially of a device, equipped with multi-coloured lamps, capable of distributing **patterns of coloured light,** or interlinking coloured shadows over the stage. It is thus essentially an apparatus for the production of special effects, presumably of less general application than the cyclorama but very useful on special occasions. The application of the idea to certain forms of decorative lighting has been, I believe, also occasionally suggested.

Arising out of this inquiry I wonder whether lighting engineers as a whole have any conception of the opportunities offered by the **amateur dramatic societies,** many of them with quite well-equipped theatres of their own. I understand that, if operatic effort is also included, there are at the present time approaching 5,000 such bodies at work in this country. In the aggregate, therefore, they constitute an important addition to the demand from the commercial theatres—more especially as

their nature often results in greater elasticity and potential originality in design.

I have observed with interest a reference in the Press to the use, in a Corinthian league match, of a **football painted a light blue.** According to the players the idea was a success. Visibility was much improved. "The ball stood out like a full moon." Apparently the colour wore off a little in the second half, and under bad weather conditions its brightness would doubtless be impaired by mud. It is believed, however, that by experiment a more lasting effect can be secured—and no doubt an occasional wash in a bucket of water would help. In the case of football played by artificial light, a light-coloured ball is essential. I believe in the experiments recently quoted in these columns (see *Light and Lighting*, October, 1946, page 175); the ball was painted white. In the daytime the advantage is naturally less, but still well worth consideration.

Fluorescent Lighting in a Hosiery Mill

The accompanying picture relates to the hosiery manufacturing shop at the Kayser-Bondor Mill at Dowlais, Glamorganshire, where 230 by 5 ft. 80-w. fluorescent lamps in Revo "Trufolite" reflectors have been installed. The very fine nature of the work demands an even concentration of glareless light with the avoidance of eye strain and fatigue. This has been achieved by the combination of fluorescent lighting and a compatible colour scheme for the walls and roof. In this particular case the roof and upper parts of the walls are painted a buff colour and the lower parts of the walls are pale green. The reflectors were manufactured and supplied by Revo Electric Co., Ltd. (Tipton, Staffs).

This is another example of the application of fluorescent lighting to the many fine processes in the silk and rayon industry.

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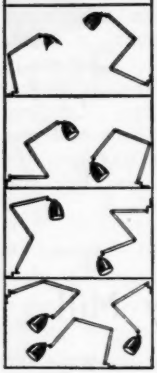

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REVIEWS OF BOOKS AND PUBLICATIONS RECEIVED

Researches on Normal and Defective Colour Vision. By W. D. Wright. (Henry Kimpton, London. 1946; *pp.* 383; *figs.* 233. *Price* 36*s. net.*)

The recently issued report of the Committee of the Colour Group of the Physical Society on Colour Blindness in Industry should serve to draw attention to this comprehensive and painstaking study of Dr. W. D. Wright, whose work in the field of colour is well known. Professor L. C. Martin, in his foreword to the book, reminds readers of a familiar preceding volume, "Researches in Colour Vision," by Sir William Abney. It is a fact that research on colour vision has been associated with the Imperial College ever since Sir William came to South Kensington in 1877. The investigations now described date from 1926, when a grant was made by the Medical Research Council. In the preface Dr. Wright mentions a number who have aided in these investigations, in which two methods of approach were adopted, the detailed study of the operations of the individual retina and the cursory examination of large groups of observers.

The results are summarised in 30 chapters, occupying nearly 400 pages, which again fall into eight main divisions entitled, respectively, Introduction, Colorimetric Equipment, The Luminosity Curve, Colour Mixture, Discrimination, Adaptation, and Defective Colour Vision, terminating with a short analysis of the Fundamental Response Curves.

Students will find in this volume a wealth of specialised information. The author reviews familiar data, but frequently enlarges upon it and suggests new ideas, drawing in some instances on data hitherto unpublished. A good feature throughout is the combination of physical research with exploration of the nature and behaviour of the eye—as illustrated by the records of differing sensitiveness of the central and peripheral regions of the retina. The discussion of adaptation (Part VI.) covers what will doubtless be new ground to many, and the analysis of defective colour vision (Part VII.) and of the available tests is informative. The book is primarily a record of experiment and the author is somewhat guarded in regard to the support of alternative theories of colour vision, though—as indeed the basis of experimentation shows—he accepts provisionally the three-response theory on the lines of Youn and Hemholtz.

The text is aided by a generous allocation of illustrations, the printing and general get-up of the book are excellent, and there are adequate Author's and Subject indexes.

Electricity in the Building Industry. By F. C. Orchard. (Chapman and Hall, Ltd. 1946; *pp.* 232, *figs.* 104. *Price* 15*s. net.*)

In a foreword to this useful work Mr. H. V. Harland, Past-President of the London Master Builders' Association, points out that hitherto there has been no work of reference sufficiently simple and wide in scope to enable builders to acquire an adequate knowledge of electricity. This need, Mr. F. C. Orchard, who is Chief Electrical Engineer and Manager to the Hornsey Borough Council, endeavours to meet. The author has been successful in presenting his subject in relatively simple

terms, and within the space available he covers a considerable amount of ground. The first three chapters dealing with fundamental principles and electrical machines may be regarded as introductory. Subsequent chapters deal with Plant Installation, Workshop Wiring and Lighting, Works Power Costs, Machine Tools and Portable Electric Tools, Maintenance of Electric Motors and Recent Research. In Chapter V. there is some reference to illumination, though we do not find any reference to I.E.S. publications or the I.E.S. Code. Chapter 8, on portable electric tools, is a useful one, and in Chapter 10, on recent research—chiefly in regard to moisture content and its testing—will be found data which would probably be new to many in the electrical industry. Three useful appendices deal with the testing of portable tools, economic considerations, and earthing tests. Doubtless any builder who fully grasps the contents of this work will be exceptionally well informed in regard to electricity and its applications. From this standpoint the author has possibly been a little too ambitious in the amount of ground he has attempted to cover; on the other hand, the wide scope of the book should render it of interest to others besides those technically concerned with building.

British Standards Institution 1946 *Yearbook*. (*British Standards Institution*, 28, *Victoria-street, London, S.W.*1. 1946; *pp.* 296. *Price* 2*s. post free.*)

This comprehensive yearbook, recently published, contains a subject index and a synopsis of each of the 1,300 British Standards now current. The Yearbook also includes lists of members of the General Council, of the Divisional Councils, and of the various Industry Committees of the Institution, as well as other useful information about its work. As noted above, the book contains nearly 300 pages of condensed information. It affords an impressive glimpse of the magnitude of the work conducted by the B.S.I., and certainly is an excellent purchase at the very moderate price of two shillings.

Physical Society: Exhibition of Scientific Instruments, etc.

The Physical Society has planned to hold the thirty-first Exhibition of Scientific Instruments and Industrial Apparatus in April, 1947, 9th to 12th inclusive, instead of the customary January, in the Physics and Chemistry Departments of the Imperial College, South Kensington, London, S.W.7. Tickets will be obtainable early in March from Fellows of the Society, and from exhibiting firms.

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